facets

further action on climate, environment, energy, economy, technology & sustainability

A Critical Review of the 2024 Greek NECP

January 2025

This work has been carried out in the scope of Contract DG-2111-67240 with the European Climate Foundation whose financial support is gratefully acknowledged.

Dimitri Lalas, Nikos Gakis and Daniela Mouka, technical personnel of FACET³S, S.A., contributed to the work described in this report.

Athens, January 2025

Summary

In this paper, a comparison is made of the final version of the Greek NECP as submitted officially to the European Commission (EC) in January 2025 that is supposed to be in line with the new enhanced European Union (EU) targets including the 55% GHG emission reduction by 2030, the Climate Laws of the EU and Greece and the legislation enacted to meet these targets with its previous two versions namely the one put out for public consultation in August 2024, with the one submitted to the EC in November 2023 which was reviewed by the EC in December 2023. In addition, the comparison also includes the 2019 version which was in line with the earlier 40% EU reduction target as well as the NC1.5 scenario, one of the two net-zero by 2050 scenarios of the Greek Long-Term Strategy Roadmap to 2050 submitted to the EC in January 2020 This scenario has been the guide for the subsequent NECPs. All these NECPs have been compiled by the Ministry of Environment and Energy under the same Government, and thus differences between them represent shifts in policy. All NECPs reflect a basic choice made in 2019 to call for a one-sided large installation of RES to meet energy demand rather than a more balanced one with equally strong emphasis in energy conservation and RES production of electricity and biofuels.

The marque targets set in the final 2024 NECP are given in the following Table S1.

Table S1: NECP Marque Targets

	2025	2030	2035	2040	2045	2050
GHG emissions reduction with LULUCF wrt 1990	38.8%	56.8%	68.1%	79.3%	88.4%	97.4%
GHG emissions reduction w/o LULUCF wrt 1990	34.1%	51.4%	61.8%	71.9%	80.4%	88.7%
Gross Inland Consumption (Million toe)	21.0	19.4	18.5	17.8	17.5	18.4
Final Energy Consumption (Million toe)	16.8	16.0	15.1	14.3	13.6	13.4
Net Electricity Production (TWh)	53.9	60.4	78.8	101.5	122.9	145.5
RES Installed Capacity (GW)	19.7	27.5	35.6	47.1	56.6	64.8
RES in Gross Final Energy Consumption	30.9%	43.0%	60.6%	77.2%	88.6%	95.8%
RES in Gross Final Electricity Consumption	59%	75.7%	96.2%	102.8%	106.9%	100.8%
RES in Heating-Cooling	51.2%	72.2%	86.0%	93.3%	95.3%	95.1%
RES in Transport	4.4%	13.4%	43.2%	69.0%	86.5%	96.1%
RES in Industry	19.7%	34.0%	43.0%	57.3%	60.6%	65.8%
Advanced BioFuels in Transport	0.8%	4.6%	11.2%	14.2%	13.5%	13.2%
RFNBO	0.0%	0.9%	5.4%	11.5%	21.5%	30.9%
Sunstainable Aviation Fuel (SAF)	1.8%	5.0%	16.2%	25.3%	32.3%	38.0%
SAF-NBO	0.0%	1.0%	4.1%	8.1%	22.4%	43.9%

As seen in the Table S1, the F2024 NECP even though it calls for a reduction in 2030 above 55%, it also calls for a disappointing 80% by 2040 and a small but non-zero remainder of 2.6MtCO2 in 2050. It also calls for a tripling of electricity production from ca 50TWh currently to 145TWh by 2050 almost all of which to be generated by RES installations and to cover over 91% of gross inland consumption. A substantial part of the RES electricity production is used to produce H2 (28.9TWh/yr by 2050) and synfuels (0.5TWh/yr by 2050), with a small amount (ca 3-4%) exported starting already before 2035. In view of the large amount of stochastic RES, storage capacity, both batteries and hydro pumping, is also included but this is not sufficient to avert a large amount (ca 6-8%, double that of grid losses) of electricity production being curtailed.

The final energy consumption (FEC) is seen to decrease in the sectors, with the decrease reaching 38% in the transport sector wrt 2025 mostly resulting from the higher efficiencies of the electric vehicles that reach high penetration rates, 24% in the industry and 18% in the residential sectors and with only the tertiary

sector consumption remaining constant. In the FEC, the use of fossil fuels is reduced to less than 7% by 2050 while electricity covers 60% of energy use.

The final 2024 NECP differs only slightly from the August 2024 version that was put out for public consultation with the largest variation (ca 6%) located in the electricity produced by 2050 which though seems to be due to a change in capacity factors of RES as the installed capacity is the same. This is an indication that the input of the over 650 submissions during the public consultation process were not effective in inducing changes.

The 2024 versions are seen to be substantially different from the 2023 one. The 2023 NECP is more ambitious in the reduction of GHG. In the energy conservation the difference is evident in the decrease of total energy use between 2025 and 2050 (11.5Mtoe vs 12.2Mtoe by 2050), in the increase of RES production (175TWh vs 145TWh by 2050) and the incorporated decrease of emission reduction (91% vs 88.7% in 2050 excluding LULUCF sinks) and in an overall backsliding of ambition (87.1% vs 79.8% emission reduction in 2040). This carries over also in the production and use of H2 and synfuels which are more than double in the 2023 NECP leading to export of H2 and synfuels vs. export of electricity in the 2024 NECPs. At the same time, the 2024 versions call for considerably smaller amounts of investment than the 2023 one (€382Billion vs €231Billion only for transport and €747Billion vs €436Billion in total over the 2025 to 2050 25-year period) which might be one of the reasons for scaling back.

All versions are seen to be improvements compared to the 2019 NECP both as to ambition and the details (most of which in the 2019 NECP refer to the 2020-2030 period with some going on up to 2040) including the use of RES and the reduction of fossil fuel use in view of the lower targets that it was designed to meet. Finally, it is of interest to note that the NC1.5 scenario of the LTS Roadmap 2050 in the majority of indices (only values in 2050 are available but with the 2030 ones constrained to match the 2019 NECP ones) is seen to lie between those of the 2024 and the 2023 NECP ones which shows that the 2019 political choice of large RES installation has been the guiding principle for all subsequent versions of the NECP.

In short, if one is to single out the major shortcoming of the final 2024 Greek NECP on which to pronounce judgment, its unambitious trajectory to 2050 that leaves a very large amount of effort to reach net zero by 2050 in the last 10-year period 2040-2050, would be clearly the one, followed next by the limited increase in energy efficiency.

The 2024 Greek NECP

In view of the new, much more ambitious target of 55% GHG emission reduction with respect to (henceforth wrt) 1990 that has been adopted by the European Union and the passage of its Climate Law, and pursuant to Art 14 of Regulation (EU) 2018/1999, for the period 2021-2030, Member States are to submit draft updated integrated NECPs by 30 June 2023 and final ones by 30 June 2024 following guidance provided in Regulation (EU) 2022/2299.

In May 2022, Greece adopted its own Climate Law (L4938/2022) which calls in Art 1 for a 55% GHG emissions reduction by 2030 wrt 1990, an 80% reduction by 2040, and net zero emissions by 2050. It also calls for the establishment of 5-year sectoral emission targets (Art 8) with the first ones to be adopted in 2024 to cover the 2026-2030 period.

On 19 December 2024 the Greek Government after a summary presentation to the press in late October published[1] in the Official Journal the final version of the Greek National Energy and Climate Plan (NECP) and shortly after, on 7 January 2025 submitted[2] it formally, almost 6 months late, to the European Commission (EC). This final version, according to the Ministry of Environment and Energy (MEE), has taken into account the comments submitted during the public consultation period in September on the basis of a previous version made public in August 2024[3] which elicited over 650 comments from almost all NGOs and energy sector enterprises individually or collectively.

The August 2024 version followed the earlier version submitted to the EC on November 3, 2023. The November 2023 version[4] was in turn a revision and full expansion of a first summary release in January 2023 of a NECP version, in deck form, which was never put out for public consultation. The November 2023 version was reviewed by EC which published the results and its recommendations[5]. The August 2024 NECP makes no mention (see page 16) of the EU guidance and the way in which it was taken into account as it should have been in the drafting of the latest version.

All three versions include projections for the next 30 years up to 2050, the year by which, according to the Climate Law, the EU, and consequently all its Member States must achieve net-zero greenhouse gas emissions. (net zero emissions). Additionally, Greece in 2020 has submitted to the EU and published, as it was obligated to do, its Long-Term Strategy Roadmap 2050[6] (LTS2050) for achieving the goal of zero emissions of greenhouse gases by 2050.

The LTS2050 presented two different strategies for achieving net zero by 2050, which were elaborated in two scenarios (EE and NC). The first (EE – energy efficiency) was based on drastic energy savings in all demand sectors (reaching 123.3 TWh Final Energy Consumption – FEC in 2050) and the installation of significant amount of renewable energy sources (RES) of 38.5W by 2050 to produce 95.8 TWh in order to meet all electricity demand (72.1 TWh in 2050) and almost all remaining energy needs. The second scenario

[1] Official Journal ΦΕΚ6983Β/19-12-24 (in Greek)
[2] https://commission.europa.eu/publications/greece-final-updated-necp-2021-2030-submitted-2025_en
[3] https://www.opengov.gr/minenv/?p=13352
[4] https://commission.europa.eu/publications/greece-draft-updated-necp-2021-2030_en
[5] Assessment of the draft updated National Energy and Climate Plan of Greece SWD(2023) 929 final 17Dec2023
[6] https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://ec.europa.eu/clima/sites/lts/lts_gr_el.pdf&ved=2ahUKEwjH4OfuxtKLAxUBQfEDHb4DFfMQFnoECBcQAQ&usg=AOvVaw3i4JMyGa710kd2vRcTA8pD

(NC - new energy carriers), on the contrary, was based on a much greater utilization of RES (71.8GW by 2050) for the production of electricity (169.8TWh), which, beyond covering electricity demand (67.4TWh by 2050) in the FEC, would have been used for the significantly larger production of hydrogen and synthetic fuels to meet the remaining needs. The required investments for the NC scenario were approximately 10% higher than those for EE, without taking into account the greater domestic value added from the energy savings measures in the EE.

From these two different strategic approaches, all versions of the NECP (November 2023, August and December 2024) are aligned with and are almost identical to the NC scenario. They call for installation of 71.7 GW of RES in the 2023 NECP, and 65.1 GW and 64.5 GW in the August and December 2024 compared to 69.8 GW of the NC. The same applies to the FEC (133.7 TWh and 155.4 TWh respectively in 2050 compared to 136.7 TWh of the NC). So, the strategy of focusing on savings or even a balanced approach was rejected in favor of the much larger installation of renewable energy sources.

In the 2024 NECPs, a nuanced strategy was adopted by calling for somewhat reduced energy savings while simultaneously utilizing fewer renewable energy sources, potentially diminishing both the economic and environmental benefits from both components as opposed to an alternate mixed approach of utilizing the increased energy savings of the EE scenario and the large-scale renewable energy installations of the NC with the additional production aimed at exporting either electricity directly or its products (H2 or synthetic fuels).

Greece lately has been expressing concern on the burden to be born to meet the 55% target by 2030 as well as the new target to be agreed for 2040 following the EC proposal of 90% almost in line with the recommendation of the European Scientific Advisory Board for Climate Change (ESABCC). The latest such expression is the Greek Prime Minister's letter[7] to Commissioner Ursula von der Leyen on 14 January 2025 in which he reiterates his concern for the difficulties to meet ambitious targets, claims that "we will be dependent on gas for at least two decades" and calls for "agreeing on the top-line number for reducing emissions and letting each Member State (MS) pick its own path". The latter as Euractiv points out[8] is "watering down the current EU law, which sets for each MS a specific emission reduction target covering sectors such as transport, buildings and agriculture, which collectively account for 60% of domestic EU emissions".

These three versions of the Greek NECP in turn follow the first submissions of NECPs prior to the upgrading of the EU to 55% from 40% wrt 1990. In this earlier round, the Greek NECP was submitted[9] to the European Commission in final form in January 2019. That 2019 NECP included a 35% contribution of RES on gross final energy consumption (GFEC), a reduction of GHG emissions by 42% with respect to (wrt) to 1990, and a final energy consumption (FEC) of 16.3Mtoe by 2030, and a very ambitious schedule for decommissioning of all lignite plants by 2028.

It is then of interest to compare all these versions of the NECP and examine its evolution over this 5-year period in which the governing party and its leadership remained the same. This becomes more important in view of the fact that the Government whose term of office extends to June 2027 seems to indicate that the 80% target specified in the Greek Climate Law will remain its choice. The latest NECP of December 2024

[7] https://www.skai.gr/news/politics/nea-epistoli-mitsotaki-sti-fon-nter-laien-gia-tin-energeia-epeigon-na-kinithoume-taxytera
[8] https://www.euractiv.com/section/eet/news/greek-pm-calls-on-von-der-leyen-to-roll-back-climate-measures/
[9] https://energy.ec.europa.eu/system/files/2020-03/el_final_necp_main_en_0.pdf

calls for net emissions of 21.1MtCO2eq by 2040 which corresponds to a 79.2% reduction wrt 1990. This low ambition, even if it is barely in line with the Greek Climate Law, needs to change. Suggestions by numerous participants in the public consultation that ended In September 2024 to increase the reduction target evidently have not been taken on board. It then becomes important that in Greece, and most likely in other MSs as well, to attempt to nudge the Government to both improve its own reduction target and to support the 90% EU-wide reduction In the Council.

Beyond questioning this broader strategic selection choice, troubling aspects arise in the specific target choices that the 2024 NECP hopes to achieve with the numerous policies and measures included in the lengthy (512 pages of the 2024 NECP, 158 additional to the 356 of the 2023 NECP) latest plan.

1. Overview of the Final 2024 Greek NECP

The compilation of both the 2024 NECPs (henceforth to referred to as F2024 NECP and 2024 NECP respectively) was based on modelling solely with the use of the TIMES-MARKAL energy modelling suite in conjunction with the NTUA energy storage model, unlike for the 2023 NECP in which both TIMES-MARKAL and the PRIMES suites were utilized. The Table 1 (see Table 30 of the final 2024 NECP OGJ6983B/19-12-2024) that follows presents the main objectives of the F2024 NECP.

Table 1: NECP Marque Targets

	2025	2030	2035	2040	2045	2050
GHG emissions reduction with LULUCF wrt 1990	38.8%	56.8%	68.1%	79.3%	88.4%	97.4%
GHG emissions reduction w/o LULUCF wrt 1990	34.1%	51.4%	61.8%	71.9%	80.4%	88.7%
Gross Inland Consumption (Million toe)	21.0	19.4	18.5	17.8	17.5	18.4
Final Energy Consumption (Million toe)	16.8	16.0	15.1	14.3	13.6	13.4
Net Electricity Production (TWh)	53.9	60.4	78.8	101.5	122.9	145.5
RES Installed Capacity (GW)	19.7	27.5	35.6	47.1	56.6	64.8
RES in Gross Final Energy Consumption	30.9%	43.0%	60.6%	77.2%	88.6%	95.8%
RES in Gross Final Electricity Consumption	59%	75.7%	96.2%	102.8%	106.9%	100.8%
RES in Heating-Cooling	51.2%	72.2%	86.0%	93.3%	95.3%	95.1%
RES in Transport	4.4%	13.4%	43.2%	69.0%	86.5%	96.1%
RES in Industry	19.7%	34.0%	43.0%	57.3%	60.6%	65.8%
Advanced BioFuels in Transport	0.8%	4.6%	11.2%	14.2%	13.5%	13.2%
RFNBO	0.0%	0.9%	5.4%	11.5%	21.5%	30.9%
Sunstainable Aviation Fuel (SAF)	1.8%	5.0%	16.2%	25.3%	32.3%	38.0%
SAF-NBO	0.0%	1.0%	4.1%	8.1%	22.4%	43.9%

The main aspects that characterize the F2024 NECP are the following:

1. The net GHG emissions including LULUCF are estimated to be reduced in 2030 by 57% wrt 1990 and by almost 80% (21.1MtCO_2 compared to 101.73 MtCO_2 in 1990) 2040 as called for in the Greek Climate Law. The reduction to 2040 is not in line with the 90% overall target of the EU as proposed by the EC.
2. By 2050 full net zero is not reached as 2.6MtCO2eq are still not covered. This small amount left uncovered is despite a CCS amount of 5.7MtCO2eq utilized as well as an almost doubling of LULUCF sinks to 9.1MtCO2eq from 5.5MtCO2eq in 2022.

3. The Final Energy Consumption (FEC) including ambient is to reach 16.8Mtoe in 2025 and down to 13.4Mtoe in 2050, from 20.22Mtoe in 2005 and 15.40Mtoe in 2022 according to the Energy Balance of Greece (2024 edition). This 13% reduction (nearly 1%/yr) in 25 years is not impressive.
4. Net Electricity production is to increase to 53.9TWh in 2025 and to 145.5TWh in 2050 almost triple that of 2022 and to come by 2050 at rate of 95% from RES sources. This calls for an increase of RES installed capacity from 13,8GW in 2022 to 27.5GW by 2030 and 64.8GW by 2050. This increase is mostly in PV installations (from 5.4GW in 2022 to 35.1GW in 2050) and wind (from 4.7GW in 2022 to 24.8GW in 2050), resulting in a 43% contribution to Gross Final Energy Consumption (GFEC) in 2030 and up to 95.8% in 2050.
5. A re-affirmation of the complete delignitization by the end of 2028 is included but without any specific schedule for the currently operating units which in previous Government and Public Power Corporation (the owner and operator) were to be decommissioned much earlier and possibly as early as 2025. Under the F2024 NECP, 3 units totalling 1.106GW (out of a total of 2.6GW in early 2023) will still be operating in 2025, of which 3 will be decommissioned sometime by 2028, with the fourth, Ptolemais V which went into trial operation in December 2022 scheduled to operate till end of 2028.
6. To facilitate grid stability, pumped storage is to increase from 699MW with 5.59GWh capacity in 2022 to 2.95GW with 16.5GWh capacity in 2030 to reach by 2050 5.45GW installed power with 66.78GWh capacity. In addition, it calls for the installation of batteries to the tune of 4.32GW with 10.99Wh capacity in 2030 to reach by 2050 12.02GW installed power with 31.25GWh capacity. This still necessitates curtailment of RES stochastic production by 0.9TWh in 2030 reaching a high of 9.7TWh by 2050.
7. It calls for the production of 36kt (1.2TWh/yr) of green H_2 in 2030 to reach 169kt (5.6TWh/yr) in 2040 and 612kt (20.2TWh/yr) in 2050.
8. It also calls for the production of 69ktoe of synfuels (including synthetic ammonia) in 2030 and going up to 318ktoe in 2040 and 1204ktoe by 2050.

In the next section, a more detailed presentation of the F2024 NECP23 and its comparison to the 2024 and 2023 NECP, as well as to the pre-Fit-for-55 2019 NECP is provided. The 2019 NECP mostly covers the period from 2018 to 2030. At the same time the 2019 NECP was submitted to the EC, the Greek LTS2050[10] was also submitted. It included two near net zero by 2050 scenarios (out of a total of six) in line with the 1.5°C target of which one (EE1.5) was based on deep energy efficiency policies and measures (PaMs) and the second (NC1.5) on high levels of RES installations. The second one (NC1.5) seems to be the basis for the later NECPs and for that reason information where available and only for 2050 (as that is the only year besides 2030 for which values are available) will also be included in the comparison.

2. The general exogenous parameters inputted

In view of the longer horizon to 2050, it is first important to look at the trajectories of basic exogenous data that have been inputted into the modelling for which the TIMES-MARKAL for the two 2024 NECPs, the PRIMES for the 2023 NECP and the LTS NC1.5, and both for the 2019 NECP suite of models have been

[10] https://ec.europa.eu/clima/sites/lts/lts_gr_el.pdf. As it is available only in Greek, a detailed presentation and analysis is provided in https://facets.gr/wp-content/uploads/2023/02/Overview-Greek-NECP-LTS-FACETS-2020.pdf

utilized. In Table 2, the trajectories of GDP, Demographics, fuel and ETS emission allowance prices are shown.

In Table 2 and all tables forward, the corresponding values for the NC1.5 scenario of the LTS roadmap 2050 are also provided, highlighted with purple background, wherever available (mostly for 2050) in the rows for the 2019 NECP for compactness, as the 2019 NECP only goes to 2030 and only for some parameters till 2040.

Table 2: General Input Parameters

		2025	2030	2035	2040	2045	2050
Population (Million)	2024 final	10.3	10.1	9.9	9.7	9.5	9.3
	2024	10.3	10.1	9.9	9.7	9.5	9.3
	2023	10.5	10.3	10.1	9.9	9.7	9.5
	2019 & NC1.5	10.5	10.4	10.2	10	9.9	9.7
GDP (Billion Euro current prices)	2024 final	205.9	216.1	225.8	236	245.4	255.2
	2024	205.9	216.1	225.8	236	245.4	255.2
	2023	194.8	200.4	212.3	231.2	251.2	272.1
	2019 & NC1.5	221.7	244.7	249	275	303	326
Crude Oil Price (€/bbl)	2024 final	103	103	103	109	117	131
	2024	103	103	103	109	117	132
	2023	86.7	86.7	86.7	91.8	100.3	112.2
	2019 & NC1.5	92.2	101.6	90.3	95.9	98.7	100.4
Natural Gas Price (€/MWh)	2024 final	38	38	38	38	38	38
	2024	38	38	38	38	38	38
	2023	44	38	38	38	38	40
	2019 & NC1.5	28	29	28	30	32	33
ETS Allowance Price (€/tCO2eq)	2024 final	80	80	140	290	430	490
	2024	80	80	140	290	430	490
	2023	80	80	110	235	340	390
	2019 & NC1.5	28.8	31.2	64	127	183	380

A number of differences are seen in most parameters. The values for population reflect the fully acknowledged demographic problem of Greece, already present, as population is projected to decline with the years and at a higher rate with every subsequent version of the NECP. A second notable difference is seen in the ETS allowance prices that in the F2024 and 2024 NECPs show a sharp increase earlier after 2030 compared to those of the 2023 NECP and a much larger one compared to 2019 NECP.

3. Emissions trajectories

Turning to the major targets of the NECPs, and in presenting the results, first the overall emissions trajectories for all NECPs are given in Table 3.

The emissions for all three latest NECPs meet the 55% by 2030 target set for the EU as a whole (up from the prior 42% in 2019). This though is achieved only with the use of the LULUCF sinks. In 2040, the F2024 and 2024 NECPs call for only a ca. 80% reduction which barely meets the obligatory target of 80% as set in

the Greek Climate Law of 2022 (Art 1) and they are not aligned with the 90% target proposed by the EC. The 2023 NECP on the other hand comes closer to the 90% target in 2040 which points to a reduction in ambition in the latest NECPs. In addition, whereas the 2023 NECP includes a realistic sink contribution of 6MtCP2, the F2024 and 2024 NECPs call for almost doubling (9.1MtCO2) from present day values. The measures to accomplish this are mostly better management (i.e. by 59%) of croplands, grasslands and wetlands but also from increasing the amounts of harvested wood. Note that none of the NECPs actually reach net zero by 2050. In 2050, if one looks at emissions without LULUCF sinks, the 2019 NECP achieves the highest reductions bested only by the LTS2050 NC1.5 ones.

Table 3: NECP Marque Targets - Emissions

	NECP	2025	2030	2035	2040	2045	2050
GHG emissions reduction with LULUCF wrt 1990 (101.73MtCO2eq)	2024 final	38.8%	56.8%	68.1%	79.3%	88.4%	97.4%
	2024	39.3%	57.5%	68.2%	79.3%	88.4%	97.4%
	2023	44.0%	57.0%	72.0%	87.0%	95.0%	99.0%
	2019						
GHG emissions reduction w/o LULUCF wrt 1990 (103,98MtCO2eq)	2024 final	34.1%	51.4%	61.8%	71.9%	80.4%	88.7%
	2024	34.6%	52.1%	61.9%	71.9%	80.4%	88.7%
	2023	41.3%	54.0%	68.0%	82.0%	89.0%	93.0%
	2019	33.2%	41.0%	43.9%	46.8%		95.2%
LULUCF	2024 final	-6.2%	-6.6%	-7.2%	-8.1%	-8.6%	-9.1%
	2024	-6.2%	-6.6%	-7.2%	-8.1%	-8.6%	-9.5%
	2023	-4.4%	-4.8%	-5.1%	-5.6%	-5.8%	-6.0%
	2019						

The break-down of emissions by sector is provided in Table 4. In Table 4, emissions in the Industrial Sector are the sum of direct energy Industrial Sector emissions plus the non-energy process-related CO2 emissions plus refinery emissions except for the 2023 NECP values which do not include refinery emissions but include reductions from carbon capture (for carbon capture see Table 5)

Table 4: GHG emissions by Sector (MtCO2eq)								
	NECP	2022	2025	2030	2035	2040	2045	2050
Industry (with process emissions)	2024 final	15.1	14	11.8	10.2	7.1	6.8	6.0
	2024	15.1	13.9	11.3	10.1	7	6.5	5.5
	2023	11.7	11.4	10.9	7.6	3.3	2	1.7
	2019	14.5	14	13.2	13.0	13.2		-0.5
Residential &Teriary & Agri	2024 final	5.6	4.5	2.5	1.6	0.6	0.2	0.2
	2024	5.9	4.5	2.5	1.6	0.6	0.2	0.2
	2023	5.6	5.2	3.4	1.7	0.9	0.1	0
	2019	5.5	5	4.3	4.2	3.7		0
Transport	2024 final	20.8	21.9	19.8	15.1	10.3	5.6	1.4
	2024	21.6	21.6	19.6	15.1	10	5.2	1
	2023	16.1	19.2	16.5	11.5	5.9	3.1	0.5
	2019	18.3	17.9	17.2	16.1	15.3		0.1
Non-CO2 emissions (CH_4, N_2O, F-gases)	2024 final	20.6	17.5	15.4	14.1	13	10	8.6
	2024	20.3	17.6	15.4	14.1	13	10	8.9
	2023		14.8	12.9	11.3	8.7	7.7	7.0
	2019	20	19.5	19.3	19.6	18.6		6.0

The emissions in the industrial and transport sectors of the F2024 NECP as well as the non-CO2 ones are seen to be larger than the 2024 NECP ones with only the ones for the buildings remaining the same. It is of interest to note that by 2050, the 2023 NECP transport as well as the industrial sector emissions even after subtraction of the carbon capture amounts shown in Table 5, are lower than either of the two latest 2024 NECPs as is the reduction of the non-CO2 GHG. The NC1.5 scenario emissions by 2050 are lower still.

Turning to means of removals of GHG emissions, in Table 5 the capture of CO2 directly from the atmosphere (DAC) or from industrial units and its use as feedstock in producing synthetic fuels or other products (CCU) as well as its storage (CCS) are presented. The two 2024 NECPs carbon capture values are close but not the same for the whole 2022-2050 period with the F2024 NECP values being lower except for CCS. The 2023 NECP values are higher than both 2024 NECP ones while the NC1.5 ones are even higher in 2050 reaching almost double those in the 2024 NECPs despite the also higher RES energy production.

Table 5: Carbon Capture, Storage and Use							
	NECP	2025	2030	2035	2040	2045	2050
DAC (MtCO2/yr)	2024 final	0.0	0.0	0.0	0.0	0.0	4.5
	2024	0	0	0	0	0.5	4.5
	2023	0	0	0.1	2.5	3.2	5.4
	2019						5.6
Carbon Capture (MtCO2/yr)	2024 final	0.0	3.3	3.4	4.2	4.1	3.9
	2024	0	3.2	3.5	4.2	4.1	3.7
	2023	0	0	0	4.4	4.6	5.4
	2019						12.8
Carbon Use (MtCO2/yr)	2024 final	0.0	0.2	0.4	0.8	1.2	2.7
	2024	0	0	0.6	1.0	1.6	3.0
	2023	0	0	2.0	3.7	5.7	7.8
	2019			0	0	0	7.4
Carbon Storage (MtCO2/yr)	2024 final	0.0	3.1	3.0	3.5	2.9	5.7
	2024	0	3.0	2.9	3.2	3.0	5.2
	2023	0	0	0	4.4	4.6	5.7
	2019						11

The need for DAC is not explained in view of the fact that the amount captured from industry is higher than the one used as feedstock so that the small amount remaining (1.2MtO2 in F2024 NECP) to be stored is only a small part of CCS of 5.7MtCO2 with the rest having no other source except DAC. Furthermore, at present the only possibility for CCS is the Prinos field in Kavala which is facing permitting and financing head winds. It is estimated that it can handle 1MtCO2/yr for 25 years[11] with the possibility of an upgrade to 3MtCO2/yr which does not meet the needs for CCS as given in Table 5.

4. Energy consumption

4.1 Final Energy Consumption

As most emissions emanate from the use of energy and most PaMs are directed to address energy consumption, of interest is also the energy production and consumption. The marque energy targets for energy of the NECPs are given in Table 6.

[11] https://www.energean.com/el/home/projects-%CF%83%CE%B5-%CE%B5%CE%BE%CE%B5%CE%BB%CE%B9%CE%BE%CE%B7/h-%CE%B1%CF%80%CE%BF%CE%B8%CE%B7%CE%BA%CE%B5%CF%85%CF%83%CE%B7-co2-%CF%83%CF%84%CE%BF%CE%BD-%CF%80%CF%81%CE%B9%CE%BD%CE%BF/

Table 6: NECP Marque Targets - Energy							
	NECP	2025	2030	2035	2040	2045	2050
Gross Inland Consumption (Million toe)	2024 final	21.0	19.4	18.5	17.8	17.5	18.4
	2024	21.0	19.2	18.2	17.4	17.1	17.9
	2023	20.9	19.1	19.0	20.5	21.7	23.0
	2019	22.4	22.2	22.1	22.5		
Final Energy Consumption (Million toe w/o ambient)	2024 final	16.2	15.2	14.1	13.2	12.5	12.2
	2024	16.2	15.2	14.1	13.2	12.4	12.2
	2023	16.6	15.4	13.7	12.7	12	11.5
	2019	16.7	16.5	16.2	16.2		12.2
Electricity Production (TWh)	2024 final	53.9	60.4	78.8	101.5	122.9	145.5
	2024	53.2	59.3	75.6	96.6	117.8	136.9
	2023	58.7	64.6	78.7	112.1	149.4	175.2
	2019	55.7	57.9				169.6
RES Installed Capacity (GW)	2024 final	18.3	27.5	35.6	47	56.5	64.7
	2024	19.1	28.2	36.3	47.4	56.8	65.1
	2023	17.9	27.3	38.5	50	68.2	75.5
	2019	13.6	19.0				63.9
RES in Gross Final Energy Consumption	2024 final	31%	43%	61%	77%	89%	96%
	2024	33%	45%	64%	85%	106%	127%
	2023	44%	44%	65%	83%	97%	105%
	2019	23%	35%	38%	41%		114%
RES in Gross Final Electricity Consumption	2024 final	59%	76%	96%	103%	107%	101%
	2024	58%	77%	98%	101%	105%	101%
	2023	58%	79%	94%	96%	96%	97%
	2019	39%	61%	70%	72%		94%
RES in Heating-Cooling	2024 final	51%	72%	86%	93%	95%	95%
	2024	49%	62%	66%	83%	89%	90%
	2023	36%	46%	63%	80%	99%	100%
	2019	37%	43%	43%	43%		93%
RES in Transport	2024 final	4%	13%	43%	69%	87%	96%
	2024	7%	14%	39%	64%	82%	91%
	2023	13%	29%	98%	209%	381%	584%
	2019	10%	19%	29%	41%		51%
RES in Industry	2024 final	20%	34%	43%	57%	61%	66%
	2024	26%	41%	50%	71%	76%	78%
	2023						
	2019						

The main takeaway points from Table 6 are the following:

- The final energy consumption (FEC) in the three latest NECPs is seen to drop from 2022 to 2050 by a yearly rate from 1.4% in the 2025-30 period to 0.8% by 2050 as opposed to an almost flat trajectory in the 2019 one. In absolute terms the FEC is higher in the 2024 NECPs than in the 2023 one by about 3-4% for the whole period to 2050 but noticeably lower by about a sizable amount (13-17%) in the 2019 NECP and even with the NC1.5 in 2050. The gross inland consumption (GIC) on the other hand is seen to drop till 2045 and increase in the last 5-year period to 2050. The 2023

NECP GIC is noticeably higher (by ca 25%) than the 2024 NECP ones and increasing rather than decreasing for the whole period, an increase which in view of the decreasing trend in FEC is not reasonable nor is it justified by increased exports (see Table 13 below).

- The electricity production is seen to almost triple by 2050 as is the installed capacity (see Table 11 below) which after 2035 is by more than 85% RES reaching over 90% by 2050 with the 2023 NECP having the largest amount of 75.5GW.
- The RES contribution per sector varies substantially between the versions and often exceeds 100% (see especially the 2023 NECP values quoted) because of technical issues [12]

Of interest is also the sectoral distribution of FEC which is presented in Table 7 below.

The difference in all sectors between F2024 and 2024 NECP is seen to be negligible with all sectors showing a decreasing trend except for the Tertiary sector in which the trend is increasing slightly. The 2024 NECPs differ substantially from the 2023 NECP version which calls for lower FEC in all sectors except for the industrial one. The 2019 NECP FEC is closer to the 2024 ones.

The sectoral FECs exhibit different behaviors both intra NECP and between NECPs. The FEC in the industrial sector is seen to decrease till 2035 and remain mostly constant till 2050, whereas in the residential and the transport sectors there is a continuous reduction and in the tertiary sector an almost continuous but small increase in the 2024 NECPs but not in the 2023 NECP.

The reduction rates in the residential sector are seen to start at 1% annually in the 2025 to 2035 period, almost zero (0.1%) in the 2035 to 2040 period and up to ca 0.5% toward 2050. These rates are half of those in the 2023 NECP (2.8% in the 2026-2030 period dropping to 1.8% in the next 5-year period and further down to 0.5% in the 2036-2040 period remaining at that level till 2050) hence the lower overall FEC in the earlier NECP version. In the tertiary sector in the 2024 NECPs a small reduction of ca 0.8% in the 2025-2035 period is eliminated in the 2035-2040 and is reversed to a 0.5% annual increase to 2050. The 2023 NECP rates follow the 2024 NECP trend to 2035 but afterwards do not reverse sign but instead continue at a smaller rate of ca 0.3%. The NECP19, without the hindsight of the COVID19 effect, shows its maximum reduction rate in the residential sector earlier starting in the 2021-2025 period at 1.6% which drops down to 0.4% in the 2025-2030 period, goes back up to 0.9% and drops yet again lower to 0.25% in the last 5-year period of 2036-2040. In the tertiary sector, 2019 NECP also shows an increase but only a marginal one.

[12] The RES indicators are calculated according to a convention that follows the Eurostat standard. The denominator for the total indicator is the gross final energy consumption while the numerator includes the use of RES directly and indirectly through electricity, distributed heat and gas distribution when these contain renewable gases (e.g. biogas) or methane and hydrogen produced from RES-based electricity. The mathematical formulas of the conventional calculation can lead to values greater than 100% for the RES indicators, especially in scenarios with climate-neutral synthetic fuels.

Table 7: Final Energy Consumption by Sector (ktoe)							
	NECP	2025	2030	2035	2040	2045	2050
Industry	2024 final	2492	2197	2066	2015	1931	1904
	2024	2494	2197	2072	2021	1933	1910
	2023	3163	3095	2595	2651	2646	2659
	2019	2943	2879	2930	2968		2661
Residential	2024 final	4149	3829	3629	3526	3431	3402
	2024	4149	3829	3629	3526	3431	3402
	2023	4286	3731	3388	3277	3166	3031
	2019	4480	4465	3945	3895		3018
Tertiary	2024 final	1894	1832	1839	1848	1874	1906
	2024	1894	1832	1839	1850	1876	1908
	2023	2091	2013	1919	1809	1765	1735
	2019	2161	2281	2295	2333		1712
Transport	2024 final	7341	6878	6122	5395	4826	4595
	2024	7343	6882	6121	5388	4762	4537
	2023	6865	6391	5684	4827	4228	3905
	2019	7163	7066	6887	6815		4616
Agriculture	2024 final	344	350	345	340	345	342
	2024	271	344	350	345	341	342
	2023	191	163	167	169	169	167
	2019						178
Total	2024 final	16220	15086	14001	13124	12407	12149
	2024	16151	15084	14011	13130	12343	12099
	2023	16596	15393	13753	12733	11974	11497
	2019	16747	16691	16057	16011		12185

NB: In the residential and tertiary sectors ambient energy is not included

All those changes would have been more easily understood if information on the underlying parameters were available in all NECPs that would provide the data to differentiate between equipment and structural more widely applicable efficiency effects and PaMs results.

In the building sectors, it is interesting to also look at the utilization of heat pumps as seen through the ambient energy they provide which is given in Table 8 below (in the Residential and Tertiary sectors, the contribution of ambient energy is not included in Table 7)

Table 8: Ambient Energy (ktoe)							
	2022	2025	2030	2035	2040	2045	2050
2024 final	444	584	846	1004	1149	1181	1176
2024	444	564	831	995	1141	1173	1177
2023	421	708	990				
2019		692	876	1018	1027		

There does not seem to be any notable difference between the 2024 NECPs and the 2019 NECP. The 2023 NECP on the other hand, at least to 2030 up to which year values are given, is higher by about 20% in line with the lower overall energy use as seen in Table 7. One should also note that ambient energy reaches almost 20% of all FEC in the buildings sector by 2050.

In the transport sector the rates of the 2024 NECPs follow a similar trend to that of the residential sector, i.e. starting at ca 1.2% annually in the 2025 to 2030 period, doubling (2.3%) in the 2030-2045 period and down to ca 1% in the last 2045-2050 period. This is in line with the timing of the fleet renewal from today's ICE vehicle majority whose life cycle is coming to an end and is replaced by mostly electric ones. The 2023 version follows the same trend with rates of 1.3% till 2035 but then increases to ca 3% and remains higher ending at 1.5% by 2050. In the 2019 NECP, the reduction is negligible in the whole 2025-2040 period which explains the much higher absolute value of energy use.

In the industrial sector the reductions are mostly in the 2025 to 2035 period with the rest period to 2050 showing no changes. This is the trend both in the 2024 and the 2023 NECPs but with much higher yearly rates of ca 1.2-1.7% for the former vs, ca 0.35-0.4% for the latter. In contrast, NECP19 shows an almost flat trajectory from 2020 to 2040 (no data are available past that).

Turning to the basket of fuels used to meet final demand shown, in Table 9, even though the total FEC values might be close in all NECPs, the fuel breakdown is substantially different.

Starting with the two 2024 NECPs, a number of small differences (of the order of less than 5%) are seen, with the F2024 NECP utilizing more oil products and bioenergy and less synfuels and H2. The 2024 NECPs vary substantially from the 2023 NECP which utilizes almost double the amount of synfuels with the difference of ca 1000ktoe coming from an almost equal reduction of electricity use. This reduction in electricity use comes from the transport sector where also a larger use of H2 is envisioned in the 2023 NECP. A main difference between the 2024 and 2023 NECPs is the more realistic starting point in time and increase in rates of deployment of H2 and synfuel production (i.e. from late 2025-30 period in the 2023 NECP vs. 2040 in the 2024 NECPs). As there is no new production facility of H_2 under construction in the last 2-3 years (beyond the existing ones in the refineries for their own use) despite announced plans to do so in locations adjacent the lignite mines, it is not clear where this would come from (possibly imports?) and where it will be utilized. By 2030, the 2023 NECP calls for 55ktoe input to the energy sector, 74ktoe of FEC, 200kt H_2 (or was ktoe meant?) and 200ktoe of synfuels produced. This begs for a clearer picture of the timing, production, imports and utilization of H_2.

The 2019 NECP data only go to 2030 and are closer to those of the 2024 NECPs except for the use of NG in FEC which is almost double by 2030 especially in the industrial sector which accounts for 50% of the total NG use. The NC1.5 scenario is closer to the 2023 NECP as regards the use of biofuels and synfuels, but it calls for even smaller use of electricity in transport, to be replaced by higher use of H2.

Table 9: Final Energy Consumption by Fuel (ktoe)								
		2022	2025	2030	2035	2040	2045	2050
Oil Products	2024 final	8921	8646	7118	5372	3562	1979	616
	2024	8921	8610	7084	5382	3470	1846	497
	2023		8687	7243	4643	2042	1044	188
	2019	9106	8375	7572				32
Natural Gas	2024 final	1158	1278	1166	878	459	302	259
	2024	1158	1228	1174	928	442	298	258
	2023		1814	1376	1075	628	258	241
	2019	1243	1596	1759				519
Electricity	2024 final	4137	4355	4590	5230	6204	6846	7168
	2024	4137	4397	4594	5183	6240	6865	7177
	2023		4593	4905	5443	5953	6222	6453
	2019	4371	4425	4581				5848
Bioenergy	2024 final	1005	1348	1662	1924	2177	2198	2278
	2024	1005	1427	1703	1936	2228	2152	2185
	2023		500	681	884	987	1725	2134
	2019	1241	1337	1469				2260
H2	2024 final	0	0	0	1	48	93	126
	2024	0	0	0	5	52	97	165
	2023			30	65	214	400	553
	2019	0	0	0				912
Synfuels	2024 final	0	0	16	69	143	410	1094
	2024	0	0	16	69	204	515	1204
	2023	0	0	0	700	1200	1400	2100
	2019	0	0	0				2212
Solar Power	2024 final	318	319	346	382	422	460	496
	2024	318	319	346	382	422	460	496
	2023		225	269	308	337	330	330
	2019	296	312	411				74
Geothermal & Solids	2024 final	65	161	95	12	0	0	0
	2024	65	157	81	16	0	0	0
	2023		179	222	261	275	150	0
	2019	75	140	154				239
District Heating	2024 final	27	44	42	41	44	37	31
	2024	27	43	42	41	40	37	31
	2023		38	36	34	33	33	33
	2019	43	41	39				76
Total	2024 final	15631	16151	15035	13909	13059	12325	12068
	2024	15631	16181	15040	13942	13098	12270	12013
	2023	0	16036	14761	13413	11669	11562	12032
	2019	16375	16226	15985				12172

In view of the differences in the utilization of energy carriers especially in the transport sector, it is important to examine the production of H2 and synfuels in the various NECP versions keeping also in mind that the production of H2 is an alternative means to store electricity to be used either directly in the sectors and possibly for the production of electricity and most importantly in turn as feedstock to produce synfuels. The amount of H2 produced is the same for the two 2024 NECPs (see Table 10) but more than three times

smaller than the one in 2023 NECP by 2050 although all are close in 2030 when H2 production is supposed to start.

Table 10: H2 and Synfuel Production							
	NECP	2025	2030	2035	2040	2045	2050
H2 Production (TWh)	2024 final	0	1.2	3.2	5.6	11.3	20.2
	2024	0	1.0	3.7	6.5	12.1	20.2
	2023	0	0.9	7.4	9.7	19.1	63.6
	2019	0	1.3				33.1
Synfuel Production (TWh)	2024 final	0	0.3	2.0	4.6	7.3	14.8
	2024	0	0.8	2.3	4.0	6.3	12.0
	2023	0	0	3.5	14.0	16.3	24.4
	2019						26.6

This is reflected in the production of synfuels which for the 2023 NECPT is double, again diverging after 2030. It is also the reason for the much smaller number of batteries (see Table 12 below) in the 2023 NECP in view of the larger use of RES electricity going directly to electrolyzers to produce H_2

4.2 Electricity

Electricity plays a central role in all scenarios examined as it becomes the energy carrier of choice in all versions. In Table 11, the installed capacities and related generation from all means is shown. Unfortunately, NECP19 does not provide projections beyond 2030 and the NC1.5 installed capacity and production in 2030 is very close to that of NECP19, as this was an explicitly stated condition of the LTS2050 modelling.

The installed capacity in the two 2024 NECPs is identical and lower overall than the 2023 one with the NC1.5 being closer to the 2024 ones.

In the RES capacity, the differences are mainly in the offshore wind and PV. The extreme offshore capacity of 17.5GW in the 2023 NECP has been reduced (by ca 32%) to more realistic levels in the 2024 NECPs (11.6GW) by 2050. This amount of offshore wind especially by 2030 seems unlikely as it presupposes that it will comprise mostly floating wind turbines in view of the large coastal depth of the Greek seas and that their cost will have been decreased enough to make their use economically viable. This is also the case for PV but here the difference between 2024 and 2023 NECPs is smaller (of ca 12%) again guided by concerns of local opposition. The 2023 NECP also includes 2.1GW of biomass/biogas fired units and geothermal while in all the others they do not exceed 0.1GW which is more reasonable in view of the rather limited biomass availability in Greece and the difficulties phased by geothermal utilization this far.

The non-RES capacity is basically NG fired after 2030 as all lignite plants are to be decommissioned by 2028 at the latest and the vast majority of the islands are to be connected to the mainland grid by 2030. It is almost identical in the 2024 NECPs at ca 6.1-6.4GW and higher by 50% from that of the 2023 one.

Table 11: Electricity Production and Installed Capacity																
		Installed Capacity (GW)							Electricity Generation (TWh)							
		2022	2025	2030	2035	2040	2045	2050	2022	2025	2030	2035	2040	2045	2050
wind	2024 final	4.7	7.0	8.9	9.5	11.0	13.0	13.0	10.9	16.3	21.1	22.9	27.0	32.0	32.5
	2024	4.7	7.0	8.9	9.5	11.0	13.0	13.0	10.9	15.8	20.7	21.9	25.5	30.3	30.2
	2023		6.0	7.6	8.5	9.2	11.8	11.9		15.0	19.0	19.0	22.0	28.0	30.0
	2019	4.2	5.2	7.0				17.5	10.1	12.6	17.2				60.9
offshore wind	2024 final	0.0	0.0	1.9	3.9	5.8	8.1	11.8			0.6	15.4	22.8	32.4	46.5
	2024	0.0	0.0	1.9	3.9	5.8	8.1	11.8			0.6	14.7	21.7	30.6	43.6
	2023		0.0	1.9	6.2	9.8	15.4	17.3			6.0	18.0	31.0	49.0	58.0
	2019							2.2							
pv	2024 final	5.4	8.5	13.5	18.5	26.0	30.6	35.1	7.1	13.1	20.9	28.7	40.1	47.1	54.0
	2024	5.4	8.5	13.5	18.6	26.0	30.6	35.1	7.1	12.5	20.3	27.0	37.1	43.8	49.2
	2023		8.2	13.4	18.7	25.4	35.2	40.3		12.0	19.0	25.0	36.0	49.0	60.0
	2019	3.9	5.3	7.7				37.3	6.0	8.2	11.8				58.9
hydro	2024 final	3.4	3.5	3.8	4.3	4.5	4.9	5.2	3.9	5.5	6.1	7.0	7.3	8.3	8.7
	2024	3.1	3.5	3.8	4.3	4.4	4.9	5.2	3.9	5.8	6.4	7.4	7.7	8.6	9.1
	2023		3.1	3.8	3.8	3.8	3.8	3.9		6.0	7.0	7.0	8.0	7.0	7.0
	2019	3.7	3.8	3.9				5.1	6.4	6.5	6.6				9.2
Biomass/ gas & other	2024 final	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.6	0.4	0.0	0.0	0.1	0.0
	2024	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.5	0.4	0.0	0.0	0.0	0.0
	2023		0.5	0.6	1.3	1.8	2.0	2.1		2.0	2.0	7.0	14.0	14.0	16.0
	2019							1.8	0.5	1.0	2.5				16.9
Lignite	2024 final	1.6	1.3						5.8	4.5					
	2024	1.6	1.3						5.8	4.5					
	2023		1.5							4.8					
	2019	2.9	0.7						5.2	4.5					
Oil	2024 final	0.8	0.8	0.1	0.1	0.1	0.1	0.1	5.1	1.8	0.3	0.3	0.2	0.0	0.0
	2024	0.8	0.8	0.1	0.1	0.1	0.1	0.1	5.1	1.9	0.4	0.3	0.2	0.0	0.0
	2023		1.3	0.7	0.6	0.4	0.4	0.1		3.4	0.2	0.5	0.0	0.1	0.0
	2019	1.7	1.0	0.3				0.1	2.7	2.2	0.8				0.0
Natural Gas	2024 final	6.3	7.0	7.9	6.3	5.9	5.9	5.9	19.1	12.2	10.9	4.7	4.1	2.9	3.8
	2024	6.3	7.0	7.9	6.4	6.4	6.4	6.4	19.1	12.2	10.4	4.3	4.4	4.4	4.8
	2023		6.9	7.7	5.7	5.2	2.8	4.2		16.3	11.7	2.1	1.2	1.6	2.9
	2019	6.0	6.8	6.9				7.8	21.9	19.2	18.3				23.7
Total	2024 final	22.5	28.2	36.2	42.7	53.3	62.7	71.0	52.0	54.0	60.3	79.0	101.5	122.8	145.5
	2024	22.1	28.2	36.2	42.9	53.8	63.1	71.6	52.0	54.3	60.2	78.9	102.1	124.3	146.5
	2023		27.5	35.7	44.8	55.6	71.4	79.8		59.5	64.9	78.6	112.2	148.7	173.9
	2019	22.4	22.8	25.8				71.8	52.8	54.3	57.2	0.0	0.0	0.0	169.6

NB1: The 23.7TWh NG amount in NC1.5 includes 9.8TWh of H2 and 13.9TWh of both NG and syngas

NB2: The 60.9TWh electricity production for onshore wind in the NC1.5 scenario includes also the offshore production.

NB3: The total production values for the 2024 NECP includes curtailed amounts. Values for individual technology production in the 2024 NECP though, unlike the F2024 NECP do not include curtailment as the curtailed values per technology are not provided.

In view of the identical installed capacity in the 2024 NECPs one would expect also identical production for both 2024 NECPs which is the case for the total net electricity produced but not for the individual technologies production for the reason given in NB3.

It is of interest though to examine the capacity factors implied from the installed capacity and production values. It is widely accepted that offshore capacity factors should be above 43-45% for economic viability. The capacity factors for offshore wind in both 2024 NECPs start (with availability 95%) at a very low 39% and increase to an unrealistic one of 47% by 2050 (values only seen in the North Sea) by 2050. Note also that the inscribed value of 0.6TWh in 2030 is misstated and should have been 6TWh instead. The 2023 NECP uses an almost constant capacity factor of 40%. The only value available for NECP19 is for all wind including both on and offshore and only for 2030, so no comparison is possible while the mean capacity factor for the NC1.5 scenario, as there is no breakdown of electricity produced for onshore and offshore is 36%.

For onshore wind the capacity factors (with 97% availability) start again from a realistic 27.2% in 2022 and increase for the F2024 NECP to 29.2% in 2050, as are the ones for the 2023 and 2019 NECPs.

For PV, the differences are small as all NECPs have capacity factors that vary between 17.2% and 18.2% for all NECPs with the F2024 one having the high value.

Finally, looking at grid losses, all NECPs show the same expected pattern of increases in view of the much expanded grids required for both the generation and distribution of electricity but the range only varies between 3.8 to 4.9TWh for F2014 NECP, to 3.8 to 4.3TWh for the 2024 and 4.8 to 5.8TWh for the 2023 with the 2019 NECP levels till 2030 for which data are available at the lower levels of the 2024 NECP.

The RES contribution to electricity production reaches 97% in the 2024 NECPs and 98% in the 2023 NECP by 2050 much higher than the NC1.5 which only goes to 86%. Of interest is also that by 2035 the RES contribution has reached 94% to 97% respectively with very small change in the last 15 years to 2050.

4.3 Electricity Storage

The tripling of RES electricity production and especially that of PV would require for grid stability purposes substantial storage from the current (2024) 700MW of pumped storage available. In Table 12 the projected amounts of storage both in hydropumping and batteries are provided. An alternative means to store electricity is to utilize it for the production of H2, most likely with the use of electrolyzers, to be used either directly or in turn as feedstock to produce synfuels which was presented earlier in Table 10.

Table 12: Electricity Storage

	NECP	2025	2030	2035	2040	2045	2050
Batteries (GW)	2024 final	0	4.3	6.9	8.7	10.4	12.0
	2024	0	4.3	6.9	8.7	10.4	12.0
	2023	1.9	3.1	3.6	8.8	19.1	22.6
	2019	0	1.3				3.0
Pumped Storage (GW)	2024 final	0.7	1.9	3.0	4.5	5.3	5.5
	2024	0.7	1.7	2.9	4.5	5.3	5.5
	2023	1.4	2.2	2.2	2.2	2.2	2.2
	2019	1.5	1.5				1.5

Pumped storage is more similar between NECPs as it depends on the available sites and is limited by the high cost of construction. The timing of its expansion starts very early as by 2030 it seen to reach from the

current 0,7GW to more than double i.e. to 1.7-1,9GW in the 2024 and even higher to 2.2 GW in the 2023 NECP at which point the 2024 NECPs diverge from the 2023 one increasing continuously but not linearly till the 5.2-5.5 GW by 2050. The 2023 NECP remains constant at 2.2GW till 2050 and closer to the NC1.5 which in 2050 is only at 1.5GW, a value very conservative but possibly more realistic.

In view of the limitations in pumped storage, batteries are called already starting in 2030 to play a very large role. The battery storage capacities of both 2024 NECPs are the same with a substantial jump for batteries from zero in 2025 to 4.3GW in 2030 and an almost linear increase to 12GW in 2050. The storage installation inscribed in NECP23 is much higher, again with a jump from zero to 5.6GW in 2030 increasing also to 8.8GW by 2040 but then jumping again to 19.1GW in 2045 to reach 22.6GW by 2050 almost double that of the 2024 NECPs. As for pumped storage, the NC1.5 includes a very small amount of batteries at only 3GW.

As both storage means should be utilized in concert, whereas the 2024 NECPs have balanced amounts of hydro pumping and batteries (with ca 66TWh battery and 31TWh hydro pumping storage and the same ratio installed power), the 2023 NECP is mostly dependent on batteries which are more aimed at short term response.

4.4 Imports and Energy Dependence

Of interest is also to examine imports (see Table 13). The two main ones, oil (larger by more than an order of magnitude from the second, NG) and NG, follow diverging paths as by 2040 the 2024 and 2023 NECPs imports are half of those for NECP19. Oil imports by 2050 are almost all feedstock to refineries to cover inland consumption (about 12% including for bunkering) and the rest for export. It should be mentioned that in 2022 nearly 60% (18.68Mtoe out of 30.77Mtoe) of the refineries' output is exported.

Net electricity imports are small and close for the two 2024 NECP versions until 2030 after which year they both reverse sign and become exports (negative values in Table 13) but with the F2024 amounts larger by ca 20% and with a peak in 2040. Given the tripling of total generation by 2050 in all NECPs, the percentage of net imports decreases to less than 3% by 2050 from near 8% currently. It should be noted that 2024 is the first year that Greece became a net exporter of electricity, possibly a sign for the future. In the 2023 and 2019 NECPs as well as the NC1.5 electricity imports remain at low values. These projections are based on a national energy balance and do not take into account price differentials or surpluses/shortages in neighboring countries that might change this picture.

Biomass imports in the 2024 NECPs near those of the 2023 one until 2030 but then increase more slowly so that by 2050 are only ca 60% of the 2023 ones which reach 1624ktoe more than the oil products and NG imports combined.

Table 13: Net Imports by Fuel (ktoe)								
		2022	2025	2030	2035	2040	2045	2050
Oil Products	2024 final	12963	11839	9398	7260	4735	2798	1333
	2024	12963	11716	9203	7115	4626	2673	1209
	2023		12194	10206	7148	4130	2265	667
	2019	13292	12747	11612	11125	10647		
Natural Gas	2024 final	4626	3944	3838	2650	2141	1899	1985
	2024	4626	3986	3973	2905	2191	2104	1955
	2023		4088	3174	1657	1400	606	671
	2019	5074	4784	4800	4238	4230		
Electricity	2024 final	302	254	156	-233	-577	-796	-424
	2024	302	272	156	-319	-574	-956	-570
	2023		157	199	226	281	348	236
	2019	444	425	394	411	429		292
Biomass	2024 final	313	416	532	688	826	852	1002
	2024	313	469	523	690	878	934	1022
	2023		525	473	847	1089	1714	1624
	2019	301	301	362	413	415		
Others (solids, H2, NH3, e-kerosine, CH4)	2024 final	0	0	-41	33	140	323	452
	2024	0	0	30	104	286	554	741
	2023		216	191	44	-65	-1445	-1116
	2019	161	137	152	179	186		
Total	2024 final	18204	16453	13883	10398	7265	5076	4348
	2024	18204	16443	13885	10495	7407	5309	4357
	2023	0	17180	14243	9922	6835	3488	2082
	2019	19272	18394	17320	16366	15907		

As a result, the energy import dependence index (shown in Table 14) of the 2024 NECPs increases from that of the 2023 NECP which diverges after 2030 and reaches a very low 9% by 2050. The 2019 NECP information goes only up to 2030 and for that period is similar to all the other NECP values.

Table 14: Energy Dependence (%)								
		2022	2025	2030	2035	2040	2045	2050
Energy Dependence	2024 final	76.6	72.9	66	51.3	37.2	26.3	21.4
	2024	76.6	72.7	67.4	54.2	40.8	30.3	23.8
	2023	74	74	66	47	30	15	9
	2019	78	75	71	67	64		29

5. The Sectoral underlying parameters and items of interest

The detailed review of energy use per sector that follows has made use of all available information. This information at sectoral level does not cover the same aspects in all NECPs which makes comparison difficult. For example, in the transport sector details of the basic parameters in transport, namely passenger and freight tonne kilometres are not provided in the 2024 NECPs or in the official version of the 2023 NECP.

In the residential and tertiary sectors again no information on new construction rates is provided whereas in the industrial sector no information on output projections and energy efficiencies is mentioned in the 2024 NECPs. Nevertheless, insights on how energy demand and resulting emissions trajectories differ between versions can still be gained hinting at policy emphasis changes between versions.

5.1 Transport Sector

In Table 15 the energy use breakdown of the transport sector for all NECPs and NC1.5 is shown. In Table 15 the penetration of BEV and PHEV passenger vehicles is also shown. Unfortunately, the information provided in the 2024 NECPs unlike some early versions (but not the final one) of the 2023 NECP does not include some of the basic underlying parameters that shape the energy consumption and emissions of the sector, namely passenger and freight kilometres and passenger vehicle numbers.

The comparison of energy use of the two 2024 NECPs shows that there are some albeit relatively small differences (i.e. less than 10% per carrier), namely an increase of fossil fuel and biofuels use and a decrease of synfuel use in F2024 NECP with the total energy use remaining the same. The electricity use remains roughly 50% of the total in both. The fleet makeup remains the same both for passenger/light-duty vehicles (LDV) (reaching 86% and 91% of BEV/PHEV passenger and LDC vehicles respectively by 2050) and heavy-duty vehicles (HDV) which points to a possible change in efficiency used.

The 2024 NECPs provide information on the evolution of the composition of the fleet of HDV and buses which is the same for both. The HDV energy use drops from 1054ktoe in 2022 down to 675ktoe in 2050 of which 609ktoe (i.e. 90%) is electricity from 95% diesel in 2022. Regarding buses, a similar picture is seen with energy use in buses going from 342.8ktoe in 2022 with 90% diesel to a low of 153ktoe in 2040 and up to 190ktoe with a decrease of fossil fuel use to zero in 2050 and replacement with 67% electricity and the rest 33% synfuel.

The comparison of the 2024 NECPs with the 2023 NECP though brings out much larger divergence with a smaller overall energy use (by 12% by 2050) leading to smaller (by 28%) GHG emissions, but with a decrease of electricity use as also seen in BEV/PHEVs penetration, and with an increase of synfuel and H2 use by 2050.

The 2019 NECP energy use to 2030 is closer to the 2024 NECPs but with even higher energy use as well as higher BEV/PHEV penetration as seen in Table 15. In the NC1.5 scenario energy is up to 4614ktoe a little higher than in the 2024 NECP but also with higher EV passenger vehicle penetration (90.3% for BEV and PHEVs) leading to near zero emissions. In the NC1.5 scenario though by 2050 the HDV and bus fleet uses only 38% electricity, almost an equal amount (33%) synfuel and the rest covered by biofuels and H2(17%) and fossil fuel (12%).

Table 15: Transport Sector Energy Demand (ktoe)								
		2022	2025	2030	2035	2040	2045	2050
Oil Products	2024 final	6684	7011	6251	4721	3156	1709	375
	2024	6684	6940	6211	4719	3081	1575	256
	2023	6068		6068	3885	2065	1036	159
	2019	6723	6780	6439				554
Natural Gas	2024 final	14	32	131	165	172	107	91
	2024	14	30	129	169	173	103	90
	2023							
	2019	28	42	102				2
Electricity	2024 final	18	32	138	609	1175	1744	2075
	2024	18	32	146	611	1179	1758	2075
	2023	16		150	346	554	784	909
	2019	18	58	154				1754
Bioenergy	2024 final	204	267	342	548	703	763	834
	2024	204	341	379	552	702	713	747
	2023	216		534	758	963	988	922
	2019	228	283	371				785
H2	2024 final				1	48	93	126
	2024				1	50	97	165
	2023			30	65	214	400	553
	2019							484
Synfuels	2024 final	0	0	16	69	143	410	1094
	2024	0	0	16	69	204	515	1204
	2023				620	1028	1075	1398
	2019							1039
Total Energy	2024 final	6920	7342	6878	6113	5397	4826	4595
	2024	6920	7343	6881	6121	5389	4761	4537
	2023	6300		6782	5674	4824	4283	3941
	2019	6997	7163	7066	0	0	0	4618
BEV & PHEV passenger vehicles (% of fleet)	2024 final	0%	1%	7%	29%	53%	72%	86%
	2024		1%	7%	29%	53%	72%	86%
	2023		2%	9%	38%	56%	70%	81%
	2019		3%	9%				90%

In all NECPs, it is disheartening that the percentage use of rail (as measured by energy use which as this is the only index available in the 2024 NECPs) remains more of less constant and rather small (less than 1%). In the 2024 NECPs the energy use decreases after 2025 from 32ktoe to 23ktoe due to full electrification and then gradually increases to 31ktoe by 2050. In the 2023 NECP the energy use is higher (ca 47ktoe) and remains more or less constant to 41ktoe in 2050.

5.2 Residential and Tertiary Sectors

In any residential sector, efforts to reduce energy use and emissions are along three pillars, namely (a) the improvement of the building insulation by renovation and by new construction to replace demolished older buildings, (b) the reduction of energy use through the improvement of the performance of the heating and

cooling equipment and other household appliances and (c) the change of the consumption behaviour patterns of the general public in their residences. Although an attempt was made in this work to examine these three components individually, the information available (as for example data on energy savings with respect to a Business-as-Usual scenario which is not provided) was not sufficient to do so satisfactorily.

Looking at the total energy consumption (Table 16), the 2024 NECPs do not differ either in the total use or per different energy carrier with electricity providing by 2050 46% of all energy used followed by bioenergy (30%). The 2023 NECP though calls for lower overall energy (by ca 20%) but a larger percentage (61%) of electricity use. The NC1.5 calls for even smaller overall energy use and an even larger percentage of electricity (62%).

Table 16: Energy Use in the Residential Sector (ktoe)

	NECP	2022	2025	2030	2035	2040	2045	2050
Oil Products	2024 final	1285	822	289	203	67	0	0
	2024	1285	831	286	203	59	0	0
	2023	1500	1300	800	300	100	0	0
	2019	1260	676	433				1
Natural Gas	2024 final	466	545	498	294	135	86	70
	2024	466	541	513	300	135	89	71
	2023							
	2019	432	618	673				477
Electricity	2024 final	1426	1603	1664	1679	1747	1780	1759
	2024	1426	1627	1660	1676	1746	1778	1759
	2023	1524	1641	1740	1801	1847	1881	1840
	2019	1719	1744	1748				1785
District Heating (solid fuels)	2024 final	27	41	39	37	39	34	31
	2024	27	41	39	37	35	34	31
	2023	47	38	36	34	33	33	33
	2019	43	41	39				21
Bioenergy	2024 final	672	848	1039	1082	1192	1159	1152
	2024	672	848	1042	1085	1198	1165	1149
	2023							
	2019	830	843	860				360
Solar Power	2024 final	306	290	302	324	349	372	394
	2024	306	290	302	324	349	372	394
	2023	204	225	269	308	337		
	2019	281	288	377				
RES	2024 final							
	2024							
	2023	129	179	222	261	275		
	2019	126	270	336				239
Total Residential (with ambient heat)	2024 final	4278	4369	4178	4035	4009	3879	3784
	2024	4278	4379	4174	4023	4005	3877	3788
	2023	4279	4286	3731	3388	3277	3166	3031
	2019	4691	4480	4466	0	0	0	2883

To evaluate these differences in the energy use, in Table 17 information on renovation of buildings is also provided. One notes that there is no difference in renovation rates between the two 2024 NECPs. The 2023 NECP though includes a different renovation rate which is smaller till 2030, higher in the 2030-2040 period and matches the 2024 NECP rates afterwards to 2050. These renovation rates would lead to ca 42-44% of the building stock having been renovated by 2050 as compared to 8-9% currently. In addition, one should

take into account new construction for which no data are provided in the 2024 and 2023 NECPs except from a preliminary version of the 2023 NECP (accessed in January 2023) in which the new builds will comprise ca 27% of the stock by 2050. This would imply that that unrenovated stock will comprise only 30% which would lead to a substantial reduction in energy demand unless mitigated by the rebound effect of inhabitant behaviour.

In Table 17 the expenditure per renovation which drives the energy reduction is also provided. The two 2024 NECPs allocate amounts of ca €7.25k/renovation in 2025-2030 decreasing to €5.36k/renovation by 2050. This is substantially lower than the amount in the 2023 NECP version especially in the immediate years (€15.25k/renovation) and closer to the 2019 NECP (€8.5k/renovation). The NC1.5 is highest at €12.97k/renovation in 2050.

Table 17: Residential Sector Renovation Depth

		2025-30	2031-35	2036-40	2041-45	2046-50
Renovation Rate (1000 residences/yr)	2024 final	68	64	64	83	83
	2024	68	64	64	83	83
	2023	59	79	79	83	83
	2019					
Expenditure per renovation (1000€)	2024 final	7.25	6.95	6.95	5.36	5.36
	2024	7.25	6.95	6.95	5.36	5.36
	2023	15.25	10.13	10.13	8.43	8.43
	2019	8.52				12.97
Renovation Buildings (% of stock)		9.0%	17.5%	25.5%	33.5%	43.9%	54.3%
		9.0%	17.5%	25.5%	33.5%	43.9%	54.3%
		12.0%	19.0%	25.0%	31.0%		41.0%
		9.3%	14.0%				43.1%

The overall result is the reduction of the energy intensity in the Residential Sector from 132.6kWh/m^2 in 2025 (to be compared with 131.0kWh/m2 in 2022 by National Energy Balance data) to 126.1kWh/m^2 in 2030 and 111.36kWh/m^2 in 2050 for the 2024 NECPs. The 2023 NECP on the other hand show a similar reduction but with a higher rate reaching 112.6kWh/m2 by 2030 and 89.2kWh/m2 by 2050. This larger reduction is a combination of the deeper energy upgrades as evidenced by the expenditure per household and possibly the slightly higher penetration of heat pumps as evidenced by the higher use of electricity. The 2019 NECP only goes to 2030 and the reduction between 2025 and 2030 is marginal. On the other hand, the NC1.5 with similarly large expenditures for renovation shows an even smaller specific consumption of 84.85kWh/m2 in 2050.

Turning to the Tertiary Sector (Table 18), the 2024 NECPs show a continuous increase in energy consumption of 30%, rather than a decrease, from 2078ktoe in 2022 to 2700ktoe in 2050 which is due to an increase of 17% in electricity consumption that comprises 90% of all energy used (after subtracting ambient energy) by 2050. This increase in electricity goes to a large percent to heat pump use, that results in larger ambient energy which increases from 348ktoe in 2022 to 794ktoe by 2050. In the 2023 NECP, electricity use is even higher reaching 1937ktoe by 2050 (on p348) a value that is clearly in contradiction with the overall use of 1735ktoe (on p343) so no meaningful comparison is possible. In general, the breakdown of the tertiary sector use in the 2023 version is either non-existent or problematic.

Table 18: Tertiary Sector energy Demand by Fuel (ktoe)								
	NECP	2022	2025	2030	2035	2040	2045	2050
Oil Products	2024 final	121	113	62	40	20	0	0
	2024	121	114	62	40	20	0	0
	2023							
	2019	159	137	112				0
Natural Gas	2024 final	109	146	117	61	12	10	16
	2024	109	145	107	67	10	10	17
	2023							
	2019	163	218	214				0
Electricity	2024 final	1480	1563	1539	1598	1680	1723	1728
	2024	1480	1573	1547	1592	1687	1722	1728
	2023							
	2019	1541	1521	1539				1558
District Heating (solid fuels)	2024 final	0	3	3	4	5	3	0
	2024	0	2	3	4	5	3	0
	2023							
	2019	0	0	0				0
Bioenergy	2024 final	8	8	68	76	59	49	59
	2024			69	49	55	47	61
	2023							
	2019	9	8	11				36
Solar Power	2024 final	12	29	44	58	73	88	102
	2024	12	29	44	58	73	88	102
	2023							
	2019	15	24	34				42
Total (with ambient heat)	2024 final	2078	2242	2331	2436	2512	2607	2700
	2024	2078	2241	2330	2437	2514	2609	2702
	2023	2227	2091	2013	1909	1809	1765	1735
	2019	2177	2331	2451	0	0	0	1636
Renovation Rate (% of stock)	2024 final							
	2024							
	2023		5.0%	7.3%	10.2%	14.0%		21.0%
	2019							21.7%

Renovation also is envisioned for the tertiary sector. In the 2024 NECPs, the only pertinent information is the commitment to meet the 3%/yr renovation of public buildings and to comply with Directives 2023/1791 on energy efficiency and 2024/1275 on energy performance of buildings (recast). No quantitative information is available past 2030 for the 2024 NECPs. In the 2023 NECP some information is available which is also shown in Table 18. It should be kept in mind that the 2023 NECP also includes a large amount of new construction in the tertiary sector as expected starting at an already high 33% in 2021 and increasing to 46% by 2050.

5.3 Industrial Sector

The use of energy in the Industrial Sector is given in Table 19. The main fuel in the 2024 NECPs which do not differ from each other is seen to be electricity which reaches 72% by 2050 from 40% in 2022 excluding feedstocks. The overall energy use is seen to gradually decrease to 1903ktoe in 2050 from 2566ktoe in 2022 which is a 26% reduction. The 2023 NECP energy use instead increases to 2030 then decreases sharply to 2035 and remains steady at ca 2600ktoe till 2050, substantially higher than the 1910ktoe of the 2024 NECPs. Unfortunately, no quantitative breakdown is provided except for electricity use which again is the main carrier and increases by 45% by 2050 wrt 2022 reaching 60% of total use.

Table 19: Industry Energy Demand (ktoe)

		2022	2025	2030	2035	2040	2045	2050
Solid Fuels	2024 final	65	161	95	12	0	0	0
	2024	65	157	81	16	0	0	0
	2023							
	2019	159	139	153				0
Oil Products	2024 final	788	644	465	364	283	240	219
	2024	788	670	474	376	274	241	219
	2023							
	2019	964	782	588				4
Natural Gas	2024 final	569	555	420	358	140	99	82
	2024	569	512	425	392	124	96	80
	2023							
	2019	620	718	770				40
Electricity	2024 final	1023	913	1003	1110	1366	1363	1374
	2024	1023	931	1003	1064	1399	1370	1383
	2023	1046						
	2019	1093	1102	1140				1472
Bioenergy	2024 final	121	219	213	218	223	227	228
	2024	121	224	213	220	273	227	228
	2023							
	2019	174	203	227				471
H2	2024 final	0	0	0	0	0	0	0
	2024	0	0	0	4	2	0	0
	2023							
	2019	0	0	0				275
Total	2024 final	2566	2492	2196	2062	2012	1929	1903
	2024	2566	2494	2196	2072	2072	1934	1910
	2023	3163	3163	3095	2595	2651	2646	2659
	2019	3010	2944	2878				2262

In the industrial sector, the two main indices of interest are (a) the output and (b) the energy intensity which may be expressed as energy consumed either vs. output or vs value added in economic terms. The 2024 NECPs do not provide information for these indices while the 2023 NECP provides both. The NECP19 only includes intensity indices in terms of energy vs value in Euros. In Table 20, the industrial output projection to 2050 in the 2023 NECP is shown. As the 2023 NECP is only a year before the 2024 NECPs it is reasonable to assume that the projections would have also been adopted in the latest NECPs. Looking at the most important, also from value added point of view, alumina production is seen to increase by about 25% while aluminium will remain steady; cement is also seen to increase by ca 17% as is ceramics while steel remains more or less steady. Almost all subsectors show increases in output reaching in some to 25% (petrochemicals, fertilizers). In view of the energy consumption (excluding feedstock) shown in Table 19 which decrease or remain steady in all NECPs, the energy efficiency is expected to improve.

Table 20: Industrial Production (from 2023 NECP)								
	2019	2020	2025	2030	2035	2040	2045	2050
Iron and Steel Electric arc steel (kt)	1253	1323	1339	1372	1345	1376	1366	1356
Non Ferrous metals								
Alumina (kt)	917	977	1179	1196	1205	1206	1207	1208
Primary aluminium (kt)	173	181	189	198	197	198	199	199
Lead (kt)	28	30	30	31	31	31	31	31
Ferrro-alloys (kt)	102	105	110	115	115	116	116	116
Nickel (kt)	17	17	18	18	18	18	18	18
Secondary Aluminum (kt)	351	301	355	379	378	383	383	383
Other nonferrous (kt)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Chemicals								
Fertilizers (vol. indic.)	470	473	481	508	514	544	562	576
Petrochemicals (vol. indic.)	205	204	211	218	223	239	249	258
Other chemicals (vol. indic.)	30	30	34	37	39	41	44	47
Low energy intensive chems (VA in €)	974	967	1032	1089	1170	1267	1319	1377
Paper and Pulp Paper (kt)	459	472	454	467	460	476	477	477
Non-Metal Minerals								
Cement kilns with clinker (kt)	6034	5903	6295	6964	6874	6923	6902	6935
Glass primary (kt)	72	68	63	63	65	67	67	67
Glass recycled (kt)	34	30	32	33	35	37	38	39
Ceramics (vol. ind.)	111	102	115	122	125	130	134	137
Other nonmetallic minerals (vol. indic.)	186	178	190	197	194	205	209	213

In Table 21, some subsectors for which information is included in the 2023 NECP from which a calculation of energy efficiency possible are highlighted. In Table 21, the corresponding values for output and energy intensity for the years 2019-2021 from the latest EU JRS IDEES data base[13] are also provided (with blue numbers) for comparison.

Table 21: Industrial Energy Efficiency (from 2023 NECP)												
	2019	2019	2020	2020	2021	2021	2025	2030	2035	2040	2045	2050
Iron and Steel (kt)	1253	1350	1323	1408	1372	1498	1339	1372	1345	1376	1366	1356
Iron and Steel (ktoe/kt)		0.106		0.106	0.150	0.097	0.183	0.165	0.133	0.099	0.088	0.084
Cement (kt)	6034	5540	5903	5272	6874	6678	6295	6964	6874	6923	6902	6935
Cement (ktoe/kt)		0.071		0.071	0.108	0.069	0.115	0.105	0.097	0.107	0.105	0.106
Paper (kt)	459	469	472	469		469	454	467	460	476	477	477
Paper (ktoe/kt)	0.108	0.164	0.115	0.150	0.150	0.152	0.183	0.165	0.133	0.099	0.088	0.084

The efficiency is seen to increase substantially in all subsectors by virtually 50% which is a rather large number, and one wonders where such optimism comes from as for these subsectors, energy consumption is a crucial economic parameter, and all efforts would have been made to improve it. In addition, there seem to be some differences in the efficiencies with respect to those of IDEES which are up to date. For example, for cement, the efficiencies in the 2023 NECP are much higher than the current ones in IDEES and also the EU average which in 2022 was 0.0925ktoe/kt[14]. This is the case also for the steel efficiencies in view of the fact that the Greek installations use arc furnaces and are already some of the best in the EU.

[13] https://data.jrc.ec.europa.eu/collection/id-0110
[14] https://www.odyssee-mure.eu/publications/efficiency-by-sector/industry/cement-unit-consumption.html

6. Policies and Measures to meet the targets

The bulk (ca 40% of the pages) of the NECPs presentation is devoted to the description of policies and measures (PaMs) to achieve the targets presented in Table 1 and some additional ones detailed in Table 5. A summary of the main policy pillars and the accompanying measures is given in Table 22.

The two 2024 NECPs differ only in an additional measure in the RES promotion pillar which aims to provide support for the training of personnel for the installation and maintenance of RES technologies. The 2024 NECPs have included an extra pillar for Research, Innovation and Competitiveness that is not present in the 2023 NECP but was included in the 2019 one. The LTS2050 report was rather short and did not include detailed description of measures.

Table 22: Policies and Measures

	2019 NECP		2023 NECP		2024 NECP		2024Final NECP	
Policy Pillars	**Policies**	**Measures**	**Policies**	**Measures**	**Policies**	**Measures**	**Policies**	**Measures**
1. Climate change, GHG emissions and removals	9	15	9	35	9	28	9	28
2. Promotion of RES	11	27	8	16	8	23	8	24
3. Alternative and climate-neutral gaseous & liquid fuels development								
Development of biomethane			1	8	1	6	1	6
Develop of green H2 & renewable liquid fuels			1	11	1	7	1	7
4. Energy efficiency improvement	12	47	10	30	11	30	11	30
5. Energy security	5	18	5	14	5	16	5	16
6. Internal energy market	9	20	5	10	5	12	5	12
7. Exploitation of critical mineral raw materials		2		2		2		2
8. Agri, shipping & tourism energy conservation	7	32						
9. Climate adaptation measures and policies in the context of implementation of the NECP	in P.1		in P.1		Yes		Yes	
10. Research, Innovation and Competitiveness	11	10			11	15	11	15
Total	64	171	39	126	51	139	51	140

The number of measures is too large to provide here a critical review (for which adequate quantitative information is anyway unfortunately not included), and a meaningful comparison of them between the NECPs. Furthermore, there is no direct correspondence with the 77 PaMs in total declared in the EEA database[15] in 2023 for which estimates of emission reduction are provided. An exemption is the sinks in LULUCF for which estimates are provided in the 2024 NECPs for capacities with both WEM and WAMs. Still, it is interesting to mention some differences in the various policies included per pillar to provide a feeling for changes in emphasis.

- In Pillar #1, the 2023 NECP includes adaptation as a policy as does the 2019 NECP, but not industry while 2024 NECPs include adaptation as a full pillar. The 2019 NECP includes policies for reduction of F-gases and the involvement of the financial sector.

[15]https://pam.apps.eea.europa.eu/?source=%7B%22track_total_hits%22%3Atrue%2C%22query%22%3A%7B%22match_all%22%3A%7B%7D%7D%2C%22display_type%22%3A%22tabular%22%2C%22sort%22%3A%5B%7B%22Country%22%3A%7B%22order%22%3A%22asc%22%7D%7D%2C%7B%22ID_of_policy_or_measure%22%3A%7B%22order%22%3A%22asc%22%7D%7D%5D%2C%22highlight%22%3A%7B%22fields%22%3A%7B%22*%22%3A%7B%7D%7D%7D%7D

- In Pillar #2, the 2023 and 2024 NECP policies are the same, with the 2019 adding one for enhancing biofuels in transport which is a part of Pillar #3 in the rest NECPs.
- In Pillar #4, the 2024 NECPs as compared with the 2023 one include a policy for the application of the "Energy Efficiency First" principle, while the 2019 NECP includes policies specifically for transport but not for energy poverty which is present in all the others.
- In Pillar #5, all policies are the same but with some in the 2019 one phrased slightly differently
- In Pillar #6, the 2023 and 2024 NECP policies are the same and differ almost entirely from those of 2019 NECP that calls for measures to enable the full operation of the Target Model including unbundling.
- Pillar #7 is the same in all NECPs although the measures included are not fully analyzed.
- Pillar #8 is only found in the 2019 NECP
- In Pillar #9 the ways PaMs in the NECP are aligned with the national and regional adaptation plans are presented.
- Research and Innovation PaMs (Pillar #10) are included in the 2019 and 2024 NECPs but not as such in the 2023 NECP even though elements of them are found in other places.

It is clear from the above that the PaMs in all NECPs are very similar with only minor differences that are due to changes already carried out (see for example the reduction of measures from 171 in the 2019 NECP to ca 135 by 2024) or to restructuring of issues.

7. Economic aspects and Investment

The investment needs for all 4 NECP versions and for the NC1.5 of the LTS Roadmap2050 broken down by sector are given in Table 23.

Table 23: Investment by Policy Sector (mil€/yr)

	2025-2030				2030-2050				
	2019 NECP	2023 NECP	2024 NECP	2024 Final NECP	2019 NECP	2023 NECP	2024 NECP	2024 Final NECP	NC1,5
Industry	745	1,275	1,760	1,762		5,625	3,050	3,168	7,940
Residential-Building upgrading	1,535	4,055	2,596	2,463		14,860	8,748	8,917	12,360
Residential-household equipment purchases	18,560	30,870	5,346	5,259		97,155	21,987	21,996	75,220
Residential-household heat pumps			5,594	5,363			12,356	12,370	
Tertiary/agriculture -Building upgrading & heat pumps	560	595	1,228	1,227		1,760	3,613	3,617	4,160
Tertiary/agriculture equipment purchases	5,420	12,430	1,557	1,565		49,835	7,050	7,053	23,020
Transport	61,915	78,090	47,206	47,466		304,545	190,819	184,986	267,800
Electricity generation	2,180	8,830	15,877	16,044		59,998	59,844	59,560	40,040
Grids electric and NG, H2	4,365	4,880	10,939	11,939		20,140	12,304	20,000	24,300
Miscellaneous	935	4,690	2,973	2,846		47,640	18,794	18,796	16,360
Total	96,215	145,715	95,076	95,934		601,558	338,565	340,463	471,200
Total w/o transport	34,300	67,625	47,870	48,468		297,013	147,746	155,477	203,400
As % of GDP	9.9%	12.5%	8.8%	9.5%		12.4%	7.0%	7.1%	7.8%
As % of GDP (w/o transport)	4.1%	6.7%	4.4%	5.1%		6.1%	3.1%	3.2%	3.4%

In the upcoming period 2025-2030, the 2024 NECPs differ noticeably in the tertiary sector where the F2024 amount is almost triple. The 2024 and F2024 NECP23 investment needs in the 2030-2050 period are seen to be almost the same except for grids where investment is much higher (by 65%) for the F2024 one. The

comparison on the other hand with the 2023 NECP as submitted to the EC highlights a number for divergences, most prominently on the amounts for purchasing of equipment in the residential, tertiary and transport sectors. The difference is present in both the immediate period of 2025-2030 and the longer term one of 2030-2050. The NC1.5 LTS2050 scenario investments for the 2030-2050 period fall in between those of the 2024 NECPs and the 2023 NECP (the 2019 NECP did not include investment amounts beyond 2030). For the transport sector, there are no detailed comparable data provided for the number and average lifetime of vehicles to be purchased (from whence the largest differences of ca. 65-69% arise) to be able to pinpoint this difference on purchase price differential or on the amount of purchases and replacement rates. An approximate calculation with current yearly sales figures in Greece (325693 vehicles of all kinds of which 70% new and the rest imported second-hand) would indicate amounts of the order of €45 billion for the 2025-2030 period which is of the order of the investment in the 2024 NECPs. This amount increases to ca €60 billion if all new vehicles registered are new which is close to the 2019 NECP but still lower than the 2023 NECP. The same is seen in the residential and tertiary sector equipment costs which are almost triple in the 2023 NECP. A possible explanation for that might be the product lifetime assumed. In the Miscellaneous category again the 2023 NECP is much higher than the others, but this is because it also includes the additional investment needed for producing synfuels at more than double volumes (see Table 10).

The investment costs for the implementation of the NECPs are also provided as a percentage of the GDP (in market values). The investments are seen to absorb a substantial percentage of GDP, with those in the 2023 NECP being considerably higher. The annual percentage is higher in the 2025-2030 period than in the years beyond. The NC1.5 percentages are approximately the same with those of the 2024 NECPs despite the higher amounts because of the much higher GDP values assumed. Note also that the cost of vehicles is almost half of the total investment needed which also put a burden in the Greek balance of payments which is already too high, as Greece has no automobile industry.

8. Some Concluding Remarks

In the previous sections the main features and quantitative information of the final NECP submitted late in January 2025, together with its precious version put out for public consultation in August 2024, have been presented and where possible compared with the earlier version NECP submitted in 2023 and but also with the one from 2019 before the adoption of the new 55% target by the EU as well as the NC1.5 Net Zero scenario of the Greek LTS Roadmap to 2050, also submitted in 2019, which has turned out to be the guide for all the succeeding NECPs.

The **first** main point that needs to be highlighted is the very unambitious target of 80% overall emissions reduction by 2040 wrt 1990 which is well below the 90% proposed target by the EC. This is a retrograde move from the 87% target in the original 2023 version signalling a change in the Government position on green transition and its willingness to be on the forefront as was advertised after 2019. It is also a clear indication of its position in the upcoming negotiations for adopting the proposed 90% target. This will not contribute to the effort to reach net zero by 2050 and simply unloads the task to next generations.

The **second** point to be made is that the input of the public consultation on the 2024 NECP resulted in negligible changes either in energy consumption and efficiencies and emissions or in the policies and

measures and expenditures, which unfortunately gives the impression of disdain of the more than 650 submissions and suggestions therein.

The **third** point to be made is the adherence to the emphasis on the installation of a large amount of RES vs. deep energy conservation and efficiency improvements as for example utilized in the EE1.5 scenario of the LTS2050 submission which ended up with a FEC of 10.62ktoe by 2050 vs 12.18ktoe of the NC1.5 scenario for which is very close to the 2024 NECP ones (12.2ktoe). This choice actually leads to an amount of energy produced overwhelmingly by RES that enables Greece to become a net exporter of electricity already by 2035 but also to a large amount of RES electricity curtailment (ca 7%) despite the storage facilities installed.

A **fourth** point has to do with the changes in the 2024 NECPs from the 2023 one from which they evolved. Even though the overall architecture is the same, there are structural differences that are indicative of the change in the last year and a half in the strategic view of the Government (which is the same since 2019 as is the Minister for Environment and Energy since the elections of June 2023). This change is evident in the incorporated decrease of emission reduction and the increase in energy use and an overall backsliding of ambition seen in several public statements[16] including the Prime Minister's recent statement that we will rely on natural gas for the next 30 or 40 and possibly 50 years[17].

A **fifth** point has to do with the information included on the ca 140 specific measures. The quantitative information provided on the expected effects of each measure despite the hundreds of pages, is either scant or non-existent so that it makes in depth analysis and cross-check of the effectiveness of the proposed PaMs to achieve the energy and emission reduction targets per sector both in 2040 and 2050 well neigh impossible, which in turn raises doubts about their applicability.

A **sixth** point that should be mentioned is the drastic change in the estimated investment needs which in the 2024 NECPs are lower by about 42% from the 2023 ones. This might be more realistic, but it has its impact on energy conservation in the housing and transport sectors.

A **seventh** point has to do with the balance between wind and solar installation. In the 2024 NECPs the onshore wind installed capacity is higher (by 8% in 2050), the offshore wind substantially lower (by 30% in 2050) and the solar lower (by 12% in 2050) compared to the 2023 NECP. There is no explanation for this shift although the offshore change is a recognition of reality and the relation of solar to wind a recognition of the need for balance for grid stability purposes. It would have been interesting to know whether other factors, social, political or economic (grid expansion costs) have also influenced this shift.

An **eighth** point of interest is the envisioned employment of H2 and synfuels. The large amount of electricity to be generated by RES going forward to 2050 will be utilized into producing H2 and synfuels to be used as feedstock and as fuel for transportation with the excess to be exported. It is clear that in the 2024 NECPs a choice was made to reduce the amount of electricity going to produce H2 and hence synfuels to almost half of that in the 2023 NECP in which an additional net amount of electricity is imported whereas in 2024 an even larger amount is exported. This reduction in H2 and synfuel production in the 2024 NECPs is also coupled with double/triple NG and oil and substantially less bioenergy use.

[16] https://www.euractiv.com/section/eet/news/greek-pm-calls-on-von-der-leyen-to-roll-back-climate-measures/
[17] Πράσινη μετάβαση: Χαμηλώνουν οι ρυθμοί - Τα μηνύματα Μητσοτάκη στις Βρυξέλλες | in.gr

A **ninth** point that should be brought up is in reference to the non-CO2 gases from the agricultural, industrial and waste sectors, and refrigeration. These GHG at 18.8MtCO2eq in 2022 comprised 24% of all emissions. In the 2024 NECPs they are all lumped together and are expected to drop down to 8.6MtCO2eq by 1950. These emissions are the largest group remaining in 2050 that needs to be matched with similar amounts of sinks to reach net zero. It would then have been important to provide more quantitative information on their evolution (for example, separate trajectories) as well as on the measures to accomplish their mitigation especially for waste instead of just stating that the EU-wide relevant legislation will be applied.

A **tenth** point refers to the inconsistency of data provided between versions and the gaps in basic underlying parameters. For example, the emissions in the F2024 NECP are given separately for the energy industries and the rest industries but not for the 2024 NECP; the 2019 and the 2024 NECPs provide summary energy budgets but not the 2023 NECP; underlying data on transport such as passenger and tonne kilometres, or on the number of commercial buildings and the depth of energy upgrades, or finally on CAPEX costs of individual technologies (RES, electrolyzers, storage etc) are partially available in the 2023 NECP only. All of these are clearly available to the Group tasked with the compilation of the NECPs and have been used in the modelling by either TIMES-MARKAL or PRIMES. This lack of consistency and gaps in important underlying parameter information provided makes target and key indicator comparison and policy shifts identification difficult.

An **eleventh** point that should be tabled is the horizon extent of all the latest NECPs that correctly now goes to 2050. This basically replaces the LTS submissions which should be cancelled provided the efforts for their compilation are transferred to providing additional depth on underlining parameters and the PaMs included in the NECPs

A **twelfth** point worth mentioning has to do with the projections of the energy prices incorporated to guide cost estimates and possibly choices if economic optimization was attempted. The experience of the last two years has shown that projections of fuel prices are uncertain. The fuel prices in 2030 between NECP19 and NECP23 differ by as much as 300% and not only in the very near years. This requires a sensitivity analysis which is not included.

As a final comment, one cannot but regret the lack of political will to accelerate approaching near zero emissions as inscribed in its Climate Law as soon as possible based the final version of the NECP trajectories. One would also wish that the underlying assumptions and full results of the modelling have been made available which would have resulted in a more informed analysis of the efficacy of the means to achieve its targets including at the important intermediate signpost of 2040 and a formulation of alternative policy proposals.